Standard Operating Procedure

for

Routine Operation of the Mirco-Orifice Uniform Deposit Impactor (MOUDI) in CRPAQS

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Note: This SOP does not include any of the figures, DRI should be contacted to obtain a hard-copy with the figures.

1.0 GENERAL OPERATIONS

1.1 Purpose of Procedure

This standard operating procedure describes the operation of the Micro-Orifice Uniform Deposit Impactor (MOUDI) for the collection of suspended particulate matter on substrates which are amenable to different chemical analyses. The MOUDI is a cascade impactor which allows air to be drawn through a series of micro-orifice nozzles; particles with different aerodynamic diameters are collected onto a series of impaction plates.

1.2 Measurement Principle

The principle of operation of MOUDI is the same as any inertial cascade impactor with multiple nozzles. At each stage, jets of particle-laden air are impinged upon an impaction plate and particles larger than the cut size of each stage are collected on the impaction plates. Smaller particles with less inertia follow the air streamlines and proceed onto the next stage. The nozzles of each succeeding stage are smaller than the prior stage, giving a higher velocity through the nozzles, and a smaller particle size cut. The air flow continues through a series of eight impactor stages until the smallest particles are removed by the after-filter.

The basic sampler is an eight-stage cascade impactor operated at a flow rate of 30 liter per minute (lpm), controlled by a ball valve downstream of the sampler. The specifications for the MOUDI Model 100 series Units A and B are given in Tables 1-1 and 1-2. The 50% cut points are 0.105, 0.148, 0.37, 0.54, 1.0, 1.8, 3.2, 5.6, and 15 μm. Nominal collection efficiency curves for a typical MOUDI sampler are shown in Figure 1-1. For this study, only the four smallest stages will be analyzed.

1.3 Measurement Interferences

The micro-orifice nozzles in the lower stages are quite small and can become partially clogged due to particle deposition by impaction or Brownian/turbulent diffusion. This could cause an increase in pressure drop. Periodic cleaning is required to minimize particle deposition.

Particle bounce between the nozzle plates and impaction plate may become significant after a long sampling period (i.e., 24 to 48 sampling hours). Material collected on the impaction plate can become re-entrained in the air flow. Circular patterns of deposit corresponding to air flow streamlines around the nozzle jets may be observed after each sampling period. The nozzle plates should be cleaned with a methanol-soaked Kim Wipe prior to each sample loading.

Figure 1-1.

Table 1-1

Desert Research Institute MOUDI Specifications for Unit A

Model No. 100 (Unit A)
Serial No. MDI-011
Flow rate: 30 lpm
Pressure reading: Upper gauge - 13.1 inch water
Lower gauge - inch water

Particle aerodynamic diameter 50% cut-points

Inlet cut-point:	15	µm
Stage 1	5.6	µm
Stage 2	3.2	µm
Stage 3	1.8	µm
Stage 4	1.0	µm
Stage 5	0.54	µm
Stage 6	0.37	µm
Stage 7	0.148	µm
Stage 8	0.105	µm
37 mm after-filter		

Table 1-2

Desert Research Institute MOUDI Specifications for Unit B

Model No. 100 (Unit B)
Serial No. MDI-012
Flow rate: 30 lpm
Pressure reading: Upper gauge - 13.3 inch water
Lower gauge - inch water

Particle aerodynamic diameter 50% cut-points

Inlet cut-point:	15	µm
Stage 1	5.6	µm
Stage 2	3.2	µm
Stage 3	1.8	µm
Stage 4	1.0	µm
Stage 5	0.54	µm
Stage 6	0.37	µm
Stage 7	0.148	µm
Stage 8	0.105	µm
37 mm after-filter		

1.4 Ranges and Typical Values

The range of concentrations measured by this method is limited by the sensitivity of the analysis instrument and the standard deviation of the values obtained by the dynamic blank.

1.5 Typical Lower Quantifiable Limits, Precision, and Accuracy

For mass concentration, the typical lower quantifiable limit is 1.0 $\mu g/m^3$ for 6-hour sampling. The precision is calculated from replicate laboratory analyses and flow rate performance tests. This precision is generally within ±10% for mass concentrations greater than 1.0$\mu g/m^3$. Accuracy is generally within the measurement precision.

1.6 Responsibilities

The field technician is responsible for carrying out this standard operating procedure and for the completion and submission of all documents.

The field operations supervisor is responsible for scheduling the field technician's visits, reviewing documentation, identifying and correcting deficiencies, and receiving samples from and transmitting samples to the laboratory.

The laboratory supervisor is responsible for preparing samples, transmitting them to the field, and receiving them from the field.

1.7 Definitions

- Nozzle Plate: Metal plate with 10 to 2,000 nozzles machined by computerized mechanical drilling. The number and diameters of the nozzles determine the particle cut size of each impaction stage.

- Impaction Plate: Metal plate downstream of the nozzle plate which holds the filter/foil substrate by means of a metal clamping ring. The impaction plate is magnetically secured on top of each impactor stage. It serves to collect particles from nozzle jets from the stage above.

- Rotator: The device for rotating the impactor stages to provide a uniform deposit. It consists of an

electric motor connected to a shaft with sprocket gears.

- Cascade Impactor: The basic assemblies of MOUDI which consists of eight impaction stages, plus an inlet and an after-filter located in the base.

- Goose-neck Inlet: U-shaped brass tube which connects the MOUDI inlet with the rotameter. It is used to check the total flow rate through the system. A bug screen is used to cover the upper part of the inlet.

- Denuder: The devices are attached to the inlet. The nitric acid denuder uses parallel plates of anodized aluminum to remove gaseous nitric acid and the organic vapor denuder uses parallel strips of prefired quartz fiber filter material to remove organic material that may adsorb on the quartz after filter.

1.8 Related Procedures

- DRI SOP # 2-102.2 Gravimetric Analysis Procedures
- DRI SOP # 2-202.2 Extraction of Ionic Species from Filter Samples
- DRI SOP # 2-203.2 Analysis of Filter Extracts and Precipitation Samples by Ion Chromatography
- DRI SOP # 2-207.2 Analysis of Filter Extracts and Precipitation Samples by Automated Colorimetric Analysis
- DRI SOP # 2-208.2 Analysis of Filter Extracts and Precipitation Samples by Atomic Absorption Spectroscopy
- DRI SOP # 2-204.3 Thermal/Optical Reflectance Carbon Analysis of Aerosol Filter Samples

2.0 APPARATUS, INSTRUMENTATION, SUPPLIES, AND FORMS

2.1 Instrumentation

2.1.1 MOUDI Unit

The MOUDI consists of three basic assemblies: a gas denuder (for either nitric acid or organic carbon vapor), the cascade impactor and the rotator. A schematic diagram of a typical MOUDI stage is shown in Figure 2-1. Each impactor stage consists of an impaction plate for the stage above it and a nozzle plate for the stage below.

The rotator unit, which rotates the stages to provide a uniform deposit on the impaction plate substrate, consists of an electric motor connected to a shaft with sprocket gears. These sprocket gears mesh with four ring gears which have been pressed onto the bodies of four alternate stages of the cascade impactor as shown in Figure 2-2. As the gear motor drives the sprocket gears, the stages with the ring gears are rotated. The stages which do not rotate are equipped with a ring and a pin which rests against the drive shaft of the rotating unit to prevent their rotation. By rotating alternate stages of the impactor and holding the others stationary, every nozzle plate/impaction plate will have relative rotation. Thus, only alternate stages need to be rotated to provide a uniform deposit on the substrate of the impaction plate.

The rotator also houses with two pressure gauges. The upper gauge monitors the pressure drop across stages 1 to 4 to provide an indication of the flow rate through the impactor. The lower gauge monitors the pressure drop across the final stage. A flow rate of 30 lpm from the inlet through the cascade impactors is achieved with a GAST 1022 pump. A ball valve downstream of the MOUDI unit is used to adjust the flow rate. A timer box with two elapsed time meters is equipped with both MOUDI units. In operation, the timer sends a current at a pre-specified time to activate the pump for sampling.

2.1.2 Impaction Plate Holder

A filter/foil substrate is loaded on top of each impactor plate and clamped into the holder by a metal clamping ring. Each impaction plate is capped with a blue color metal cover. The sealed cover minimizes evaporative loss or any contamination of the sample during storage. A set of eight impaction plates with an after filter cassette is secured by a metal holder which consists of two 2x2 inch metal plates and four long screws.

Figure 2-1. Schematic Diagram of a Typical MOUDI Stage.

Figure 2-2. Rotator Unit and Fully Assembled Unit for Rotameter.

2.1.3 Dwyer 10 to 100 SCFH Rotometer

This rotameter is used to set and verify flow rates through each MOUDI unit.

2.1.4 Sonicator (Branson Model 5200)

The ultrasonic bath is used to clean nozzle plates after each 48 hours of sampling or when the pressure drop across the impaction plate has increased and adequate pressure drop can not be achieved for sampling.

2.1.5 Spare Parts Accessories

Each MOUDI is accompanied by a carrying case with the spare parts and accessories listed in Table 2-1. Table 2-2 is a summary of the parts list for the impactor and rotator unit and the vendor's address and phone number.

2.2 Supplies

2.2.1 Forceps: Forceps are used to load and unload filters from the filter holders and to place them in their numbered PetriSlides.

2.2.2 18 x 24 inch Laboratory Bench Cover: The bench cover is the work surface used to place the filters in their numbered PetriSlides.

2.2.3 Methanol in Wash Bottle: To clean forceps and cutting board prior to filter unloading, and to clean nozzle plates between sampling.

2.2.4 Kim Wipes: To wipe methanol from working surfaces and forceps.

2.2.5 47 mm PetriSlides: Filters are placed into these slides and samples with the equivalent ID labels are transferred from the filter holder to the Petri Slide after sampling.

2.2.6 Bar-Code Labels: Bar-code labels are attached to the cover of each impaction plate holder for identification.

2.2.7 Disposable Gloves: Gloves are worn whenever filters are loaded or unloaded. Gloves are discarded when they have come into contact with any contaminant and after each loading/unloading session.

2.2.8 Teflon FEP 200A (fluorocarbon, heat sealable, 0.002 inch thick) (Cadillac Plastic and Chemical Company, Birmingham, MI): The substrate used for sample collection.

Table 2-1

MOUDI Spare Parts and Accesories

Item No.	Description	MSP Part #	Quantity
1	O-ring (body)	MOUDI-1-039 Urethane	2
2	O-ring (body)	MOUDI-1-038-Urethane	2
3	O-ring (filter post)	MOUDI-1-020-Viton	2
4	O-ring (filter holder)	MOUDI-1-025-Viton	2
5	O-ring (impaction plate)	MOUDI-1-028-Viton	2
6	O-ring (nozzle plate)	MOUDI-1-035-Viton	2
7	O-ring (trans. cover)	MOUDI-1-031-Viton	2
8	Machine screw	MOUDI-108	3
9	Teflon washer	MOUDI-109	2
10	Chem-plex silicon lub.	MOUDI-201	1
11	Cling-Surface silicone spray	MOUDI-202	1
12	Aluminum substrate 47 mm	MOUDI-203	300
13	Substrate holder ass'y	MOUDI-204	1
14	Substrate holder cover	MOUDI-205	9
15	Coating mask for 47 mm	MOUDI-206	3

Table 2-2

Summary of Parts List for MOUDI

I. Impactor (size= 35 X 8 cm, weight 3 kg)

Item No.	Description	MSP Part #	Quantity
1	Filter base	MOUDI-101	1
2	Filter base cover	MOUDI-102	1
3	Stage body	MOUDI-103	8
4	Cover	MOUDI-104	1
5	Pressure tap	MOUDI-105	2
6	Impaction plate ass'y	MOUDI-106	8
7	Filter holder ass'y	MOUDI-107	1
8	Inlet nozzle plate, 15µm	MOUDI-110	1
9	Nozzle plate, 10µm	MOUDI-111	1
10	Nozzle plate, 5.6µm	MOUDI-112	1
11	Nozzle plate, 3.2µm	MOUDI-113	1
12	Nozzle plate, 1.8µm	MOUDI-114	1
13	Nozzle plate, 1.0µm	MOUDI-115	1
14	Nozzle plate, 0.56µm	MOUDI-116	1
15	Nozzle plate, 0.32µm	MOUDI-117	1
16	Nozzle plate, 0.18µm	MOUDI-118	1
17	Nozzle plate, 0.10µm	MOUDI-119	1
18	Nozzle plate, 0.05µm	MOUDI-120	1
19	Machine screw	MOUDI-108	24
20	Teflon washer	MOUDI-109	9
21	O-ring (body)	MOUDI-1-039 Urethane	10
22	O-ring (body)	MOUDI-1-038 Urethane	9
23	O-ring (filter post)	MOUDI-1-020-Viton	1
24	O-ring (filter holder)	MOUDI-1-025-Viton	1
25	O-ring (impaction plate)	MOUDI-1-028-Viton	9
26	O-ring (nozzle plate)	MOUDI-1-035-Viton	8
27	O-ring (trans. cover)	MOUDI-1-031-Viton	9

Table 2-2 (continued)

Summary of Parts List for MOUDI

II. Rotator (size= 50 X 22 cm, weight 6 kg, power 110-12V, 50Hz or 60Hz, 0.3 amp)

Item No.	Description	MSP Part #	Quantity
1	Shell back	MOUDI-151	1
2	Shell front	MOUDI-152	1
3	Panel, gauge mount	MOUDI-153	1
4	Panel, motor cover	MOUDI-154	1
5	Plate, motor mount	MOUDI-155	1
6	Plate, impactor support	MOUDI-156	1
7	Plate, base	MOUDI-157	1
8	Bearing	MOUDI-158	1
9	Bearing	MOUDI-159	1
10	Shaft ass'y	MOUDI-160	1
11	Coupling	MOUDI-161	1
12	Motor	MOUDI-162	1
13	Capacitor	MOUDI-163	1
14	Hinge	MOUDI-164	2
15	Draw latch	MOUDI-165	2
16	Keeper	MOUDI-166	2
17	Switch, on/off/mom	MOUDI-167	1
18	Light, neon	MOUDI-168	1
19	Line cord	MOUDI-169	1
20	Valve, control	MOUDI-170	1
21	Bracket, valve	MOUDI-171	1
22	Magnehelic 0-180"H20	MOUDI-172	1
23	Magnehelic 0-20"H20	MOUDI-173	1

III. Vendor's Address and Phone Number

MSP Corporation
1313 Fifth Street, S.E., Suite 206
Minneapolis, MN, U.S.A. 55414
Tel: 612/379-3963
Fax: 612-379-3965

2.2.9 Aluminum Foil: Commercial grade heavy duty aluminum foil.

2.2.1047mm Metal Punch (McMaster Carr, Sante Fe Springs, CA): Used to cut 47mm substrate discs from the FEP Teflon Sheet.

2.2.11Teflon Tape, 1/2" width x 20 ', available at hardware store: Wrap on top of the O-ring of the impaction plate to keep the metal clamping ring tightly in contract with the impaction plate holders.

2.2.1237 mm Teflon Membrane Filter (Gellman Sciences Inc., Ann Arbor, MI, #R2PJ037).

2.2.1337 mm Quartz-Fiber Filter (Pallflex Corp., Putnam, CT, #2500 QAT-UP)

2.2.14Glass-Fiber Filters (Pallflex Corp., Putnam, CT, #TX40H120-WW)

2.3 Data sheets

Figure 2-3 illustrates an example data sheet as it comes in the carrying case prior to sampling. Figure 2-4 is an example of a data sheet after it has been filled out by the field technician after sampling. MOUDI data sheets are prepared in triplicate. The pink copies are retained in the laboratory after unexposed substrates are loaded in the carrying case as part of the sample chain-of-custody. The yellow copies are kept in the field office after sampling. The original data sheets are returned to the laboratory with the exposed substrates.

3.0 CALIBRATION STANDARDS

The transfer standards for MOUDI flow rates are the rotameters specified above which have been calibrated against a Roots meter prior to the beginning of the sampling program. Figures 3-1 and 3-2 present the calibration curves for 760 mm Hg and 25° C for the rotameters used in this project. Elapsed time meters are calibrated against a stopwatch.

4.0 SAMPLER OPERATION

4.1 Flow Diagram

Figure 4-1 summarizes the routine operating procedure for the MOUDI. Filter changing and flow rate performance tests are performed between each sampling period and require approximately 20 to 25 minutes per Moudi unit.

figure 2-3.

figure 2-4.

Figure 3-1. DRI Rotameter Calibration Log Sheet.

Figure 3-2. Dwyer RMC-102 Rotameter Calibration.

Figure 4-1. MOUDI Sampler Operations Flow Diagram.

Nozzle plates should be cleaned with methanol soaked Kim Wipes during each sample change.

4.2 Start Up

4.2.1 Laboratory Operations

- Preparation of Sampling Substrate

  The substrate used in the impactor must be thin enough to be clamped in the holder by the metal clamping ring. No commercially available substrate is suited for MOUDI sampling and analysis.

  FEP (fluorocarbon) 200 A (0.002" thickness) Teflon sheet is purchased from Cadillac Plastic and Chemical Company (Birmingham, MI), and punches are used to prepare 47 mm substrate discs. These discs are then soaked in methanol overnight, rinsed thoroughly with distilled-deionized water, and dried in a vacuum oven prior to submission for sample pre-weigh. Pre-weighed Teflon sheets are stored in the individual PetriSlides with pre-assigned barcode labels.

  The aluminum foil is purchased in the grocery store and a stainless steel punch is used to prepare 47 mm substrate discs. Batches of aluminum foil substrates are pre-fired at 600° C for 3 hours and acceptance tested for background organic and elemental carbon levels. Aluminum foil substrates are stored in pre-assigned barcode labelled PetriSlides and refrigerated prior to sample loading.

- Preparation of Impaction Plates

  The impaction plates are loaded in the laboratory and inserted into the impactor sampler prior to sampling. Metal filter holder covers are provided for each impaction plate to minimize sample contamination.

  Normally, Unit A uses pre-cleaned 47 mm diameter FEP Teflon sheets as impaction plate substrates and Gelman (Ann Arbor, MI) polymethyl pentane ringed, 2.0 μm pore size, 37 mm PTFE Teflon membrane filters (#R2PJ037) as after-filter substrates for mass and ion analyses. Unit B uses pre-fired 47 mm diameter aluminum foil (Reynolds Aluminum, Gresham, OR) as impaction plate substrates and pre-fired Pallflex (Puttnam, CT) 37 mm diameter quartz fiber filters (#2500 QAT-UP) as after-filter substrates for carbon analysis.

  DRI MOUDI Field Data Sheets (Figure 2-3) with pre-assigned

barcode labels and filter holder cassette IDs are prepared; impaction plates are cleaned with a methanol-soaked Kim wipe prior to substrate loading.

A set of 8 impaction plates and one after-filter cassette is arranged sequentially on top of a cleaned laboratory counter. Each filter retainer ring is marked with 1 to 8 black dots which correspond to the stage number. The barcode label is placed on each filter holder cover, and corresponding PetriSlides with sampling substrate are placed in front of each impaction plate.

With gloved hands and a methanol cleaned forceps, load the sampling substrates one by one for each set of 9 filter holder cassettes. Substrates are put into the impaction plate holders by removing the retainer ring, inserting a substrate, and the pressing the ring back onto the holder. The filter is inserted in the after-filter holder in the same fashion. Care must be taken to align the pin on the filter holder to the hole in the ring. Complete the field data sheet before proceeding to the next cassette.

Removal of impaction plate substrates and after-filter is also done in a laboratory. To remove the impaction plate substrates, the retainer rings are lifted from the holders and the substrates removed. The same procedure is required to remove the after-filter from its holder. However, on the filter holder, there is a pin between the holder and the rings so the ring must be lifted straight up.

4.2.2 Field Operations

- Install the Denuder.

  The nitric acid denuder is installed on unit A and the organic vapor denuder is installed on unit B.

- Plug in the Sampler

  Each MOUDI unit uses approximately 8 amps of current during normal operation, though it can draw 20 amps or more when the pump starts. A 20 amp circuit is needed for each MOUDI. Where possible, the unit should be directly plugged into an outlet. If an extension cord is needed, it should be extra heavy duty (10 or 12 gauge) and not more than 25 feet in length. If the pump relay chatters when the pump is switched on, the voltage drop along the extension cord is probably too high. A heavier gauge or shorter cord usually eliminates

this chatter. When two MOUDI units are operated on the same circuit, set the current times one minute apart so that they will not draw starting currents at the same time.

- Program the Timer

  Detailed instructions for the Grasslin 56-72 timers are described below. Read them. Channels one and two control the pumps and the elapsed time meters for Unit A and B, respectively. Four features must be noted on the timer readout: 1) time of day; 2) am or pm; 3) day of week; and 4) on/off (or I/O). The on/off indicator refers to the current status of a channel -- "ON" indicates that power is on and "OFF" indicates that it is not. "I" is used in a program to turn power on and "O" is used to turn it off. The sequence of program steps is not controlled by the order in which they occur, but by the times at which they are set to occur. The timer contains a rechargeable backup battery which should last for as long as two days after a power outage.

- Set the Current Time

  Press the "Set Time" button and keep it depressed during the entire procedure. Press the button under the current day of the week until a bar appears over the day marker. Press the "h+" or "h-" button until the current hour appears in the center of the LCD display. Make certain that the "am" or "pm" designation on the left edge of the display is correct. Keep pressing the button until it is. Press the "m+" or "m-" button until the current minute appears on the display. Release the "Set Time" button and the current time should be displayed.

- Program the Start and Stop Times

  Push the "READ" and "CANCEL" buttons several times in succession until a blank display appears. This clears all previous programming steps. Push "Set Time" and the timer is prepared for programming. For example, to program the channel 1 morning start time, push "h+" until 5 am is displayed in the hours column. Push "m+" until "01" is displayed in the minutes column. Push the button corresponding to the day of the week on which bar on the LCD display should appear over each day. Press the Channel 1 "I/O" button until the Channel 1 LCD marker is on "I". Press the "WRITE" button to record this program step. To program the morning stop time, press the appropriate buttons to

obtain a time of 11:00 am on the same day and press the Channel 1 "I/O" button until the Channel 1 display marks "O". Press the "WRITE" button to record this program step. For the next sampling period of the same day, repeat the previous steps with different start and stop times. Push "h+" until 11:00 am is displayed in the hour column. Push "m+" until 01 is displayed in the minute column. Press the Channel 1 "I/O" button until the Channel 1 LCD marker is on "I". Press the "WRITE" button to record this program step. To program the afternoon stop time, press the appropriate buttons to obtain a time of 5:00 pm on the same day and press the "I/O" button until the Channel 1 display reads "0". Press the "WRITE" button to record this program step. Repeat the same procedure for Unit B on Channel 2.

- Program Verification and Modification

Press "READ" to sequence through each step in the program in order. When a change is desired in a step, press the appropriate buttons to make that change and then press "WRITE" to record the changes. Pressing "READ" will start at step number one when it is pressed following a "WRITE".

The programs should read as follows for Channel 1 on each sampling day. The same programs are applied for channel 2:

Step 1: 05:01 am, on sampling day, Channel 1 on I.
Step 2: 11:00 am, on sampling day, Channel 1 on O.

- Test the Timing and Switching Sequence

Flip the power switch to "ON". This supplies power to all sampler components. Press the channel 1 "OVERRIDE" to turn the pump on and the pump should start. Repeat the same steps for Channel 2.

- Impaction Plate Removal and Installation

Remove the impactors from the rotator by plugging the rotator into a 110 volt outlet and holding the switch on the rotator panel to " reverse." The drive shaft will rotate clockwise and the impactor will be pushed out of the rotator.

Disassemble the impactor by first removing the cover and then removing each stage of the impactor, starting with the upper stage and working downward to the base. Figures 4-2 and 4-3 show the partially disassembled impactor unit and parts of an individual MOUDI stage, respectively. Each stage of the

impactor consists of the body, the impaction plate for the stage above and the nozzle plate for the stage below. The impaction plate is held onto the pedestal of the body by twomagnets; one magnet on the pedestal and the other on the impaction plate. Normally this is all the disassembly of the stages that is required. However, if necessary, the nozzle plates can be removed by removing the three screws holding the nozzle plate to the body and pushing downward on the nozzle plate ring through the three screw holes. Caution: Never push directly on the nozzle plate, which is quite thin and can be damaged.

The final step in disassembly is removal of the after-filter holder from the base. To do this, unscrew the top of the base from the bottom and remove the top. Remove the filter holder from the base by pulling upward. After disassembling the cascade impactors, a new set of filter holders can be loaded on stages 5-8; stages 1-4 are merely wiped clean. Place the impaction plates on the pedestals of the base for each stage. Assemble the stages in the reverse order of disassembly. Assemble the smallest cut-size stage first. Progressively larger cut size stages are placed on top as one goes from bottom to top of the impactor. The impactor cut sizes are etched into the ring of the nozzle plate and can be read from the bottom of the stage. The stage ID is also labelled on the outside of the impactor. The final step in the impactor assembly is to place the cover onto the uppermost stage.

The impactor can now be placed into the rotator. By turning the rotator switch "On" for a few seconds, the gears on the drive shaft will pull the impactor into the rotator. Connect the pressure gauges to the impactor (upper gauge to the upper pressure tap and the lower gauge to the lower pressure tap) and the MOUDI is fully assembled.

Caution: apply a moderate amount of grease to the O-ring between stages when reassembling. If these O-rings become dry, the torque required to rotate the MOUDI may increase enough to damage the motor.

Figure 4-2. Partially Disassembled Impactor Unit.

Figure 4-3. Parts of an Individual MOUDI Stage.

- Operating Procedure

  Connect the MOUDI outlet to a vacuum pump. Turn on rotator and the vacuum pump. Adjust the flow to 30 lpm. The upper gauge pressure drop should read between 1 to 2 inches of

water, and the lower gauge pressure drop should read 15 inches of water. Complete the field data sheet. The MOUDI is now ready to sample aerosol.

4.3 Routine Field Operations

As shown in Figure 4-1, routine field operations consist of the following steps:

- Upon arrival at the sampling site just before 11 am, insure that the units are operating.
- Turn pump off.
- Make sure both flow rates and pressure drops are within specified tolerance (i.e., ±10 % from the initial setting). Just before 11 am connect the rotameter with the gooseneck inlet. Record the final flow rate, final pressure drop, and final elapsed time on the MOUDI field data sheet. Verify that total sampling time is within ±10% of the pre-specified duration.
- Turn pump off.
- Remove impactor from rotation unit by disconnecting the tubing between the pump and impactor, and between the impactor and pressure gauge.
- Disassemble impactor from the top to bottom.
- Cap each exposed impaction plate with the corresponding cover and remove the impaction plate from the pedestals of the base for each stage. Secure the entire set of 8 impaction plates and one after-filter cassette in the cassette holder.
- Wipe the nozzle plate with a methanol-soaked Kimwipe or disassemble the nozzle plate as stated in Section 4.2.2 and place it in a distilled water filled ultrasonic bath. Sonicate in distilled water for 10 minutes.
- Repeat the above steps for the second MOUDI.
- According to the field data sheet, install a new set of unexposed impaction plates. Starting from the bottom stage, load the impaction plate stage by stage.
- Assemble the impactors.

- Load the impactors in the rotator unit and connect the tubing between the impactor and the pressure gauge.
- Verify the program steps on the Grasslin timer.
- Turn the pump on and adjust the flow rate for 30 lpm.
- Connect the rotameter and record the initial flow rate, initial pressure drop, and initial elapsed time on the new set of field data sheets.
- Prepare the equipment for field sampling.
- The pump will be turned off at the end of each sampling period.

4.4 Shutdown

At the end of the sampling program, conduct a performance test on the flow and pressure drop prior to dismantling the sampler. Record the condition of the sampler in the station logbook. Check all equipment and parts against the check-out sheet and assure that all are packed for shipment back to the Desert Research Institute in Reno, NV.

5.0 QUANTIFICATION

5.1 Calibration Procedures

5.1.1 Mark rotameter scales with correct readings

The actual flow rate through each rotameter is

$$Q_{act} = (0.472)\ (aQ_i+b)((760/P2)(T2/298))(0.5)$$

where

Q_{act} = actual flow rate at temperature T2 and pressure P2 in lpm.

a = linear regression slope for the relationship between the rotameter reading and the true flow rate at standard conditions.

b = linear regression intercept for the relationship between the rotameter reading and the true flow rate at standard conditions.

Actual flows can be located on a piece of tape applied to the rotameter scale for typical temperatures and pressures in the sample area. Slopes and intercepts are found on the DRI rotameter calibration log sheet (Figure 3-1).

5.1.2 Connect the Rotameters

Connect the 0 to 100 SCFH rotameter to the gooseneck inlet for flow measurement.

5.1.3 Adjust Flows

Adjust the ball valve downstream of the MOUDI unit until the actual flow reads 30 lpm. Record the flow rate in the logbook.

6.0 QUALITY CONTROL

6.1 Calibration Checks

An initial and final flow rate measurement is made and recorded at every sample change.

6.2 Pressure Drop Checks

An initial and final pressure drop measurement is made and recorded at every sample change.

7.0 QUALITY AUDITING

Audits of flow rates are performed by an independent auditor with independent standards at the beginning and end of the field program.

MOUDI at Fresno and Angiola Sites

The operating period to which the following instructions apply starts 12/1/00 and ends 1/31/01. Three MOUDI samplers will operate at each site. Each sampler will collect multiple samples on different substrates for several different analyses. Samples will be collected only during Intensive Operation Periods (IOP). Each sample will be collected during one of four time periods: 0000-0500, 0500-1000, 1000-1600, or 1600-2400. The sample collection times will be set so that they are mixed among the four periods and allow for sample changes to be made after 0800 and near 1600. Samples will be collected at the same times at the two sites on a schedule that is determined in advance of the study. The time of each sample depends on the particular IOP day

The following table lists the IOP days and the times when the MOUDI samples will be collected:

IOP Day	Sample Run Period			
	0000-0500	0500-1000	1000-1600	1600-2400
1		Run		
2	Run		Run	
3		Run		Run
4			Run	
5	Run			Run
6			Run	
7		Run		Run
8			Run	
9	Run			
10	Run		Run	
11		Run		Run
12			Run	
13		Run		
14	Run		Run	
15		Run		Run
Number	5	6	7	5

Unlike the operations of other samplers, the sample changing times for the MOUDI samples cannot be at the same time on each IOP day but will change depending on the sample was collected. The following table lists the times at which the sample substrates should be loaded on and removed from the MOUDI samplers. In some cases, the samples can be removed and loaded during the same time period. For other samples, the loading has been delayed several hours after removing the previous samples to limit the time the samples sit on the sampler. It also should be noted that it is highly unlikely that all fifteen IOP days will run consecutively so that some of the designated removal times will be on a day after a particular IOP ends and some of the designated loading times will be on a day before the next IOP begins. This could affect removals during the 0800 to 1000 period and the loadings during the after 1600 and 0800 to 1000 periods.

IOP Day	Sample Change Time			
	Between 0800 & 1000	After 1000	Between 1400 & 1600	After 1600
Before 1				Load
1		Remove		Load
2	Remove/Load			Remove/Load
3		Remove	Load	
4	Remove/Load			Remove/Load
5	Remove		Load	
6	Remove/Load			Remove/Load
7		Remove	Load	
8	Remove/Load			Remove/Load
9	Remove			Load
10	Remove/Load			Remove/Load
11		Remove	Load	
12	Remove/Load			Remove/Load
13		Remove		Load
14	Remove/Load			Remove/Load
15		Remove	Load	
After 15	Remove			

A Grässlin Model Digi 42/2 timer controls the operation of the MOUDI pumps and sample turning motors. At least initially, one pump will be used for all three MOUDIs. An additional pump may be necessary if the required flows cannot be attained. The programs should remain the same although the distribution of power may change. In the current configuration, channel 1 turns the pumps on and off and channel 2 turns the motors for the sample rotation on and off. Since the programs are not the same for each day, all the programs cannot be installed in the timer at the start of the study. The On and Off times and the day of the week for the next sample will have to be programmed at the time the sample substrates are loaded onto the sampler. The program for the first sample can be entered into the time to run on all days. When the day of the first IOP is known, the correct day for the first sample can be entered into the timer and the programs enabled (denoted by 🕒). Before and after any IOP, both channels of the timer should be left in the Fixed Off mode. The following pairs of programs are used to control the MOUDI samplers:

Sample Time	Channel	Day depends on IOP	Time	On/Off	Program Status	
					Non-IOP	IOP
0000-0500	1, 2	MTWTFSS	12:01 AM	On	**Fixed Off**	🕒
	1, 2	MTWTFSS	5:00 AM	Off	**Fixed Off**	🕒
0500-1000	1, 2	MTWTFSS	5:00 AM	On	**Fixed Off**	🕒
	1, 2	MTWTFSS	10:00 AM	Off	**Fixed Off**	🕒
1000-1600	1, 2	MTWTFSS	10:00 AM	On	**Fixed Off**	🕒
	1, 2	MTWTFSS	4:00 PM	Off	**Fixed Off**	🕒
1600-2400	1, 2	MTWTFSS	4:00 PM	On	**Fixed Off**	🕒
	1, 2	MTWTFSS	12:00 AM	Off	**Fixed Off**	🕒

1. On the day prior to the first IOP:

    a. Sample substrates are loaded on the MOUDIs after 1600.

    b. The timer is programmed to turn the pumps and sampler turning motors on at 0500 on the next day and off at 1000. The timer programs are enabled.

2. On the first day of the first IOP:

    a. The sample substrates are removed after the sample ends at 1000.

    b. Between 1400 and 1600, the substrates for the second sample are loaded on the samplers. The timer is programmed to turn the pumps and sampler turning motors on at 0000 and off at 0500 on the next day. The timer programs are enabled.

3. On subsequent days of the first IOP:

    a. Samples will be loaded and removed following the set schedule.

4. On last day of the first IOP:

    a. Announcement as to end of the IOP will be made by 12 noon on the last day.

    b. Samples scheduled to run on this IOP day will be loaded on the samplers at the scheduled times.

    c. Samples scheduled to be loaded on this IOP day but run on the next IOP day will be not loaded on the samplers. The timer programs will be set to Fixed Off.

5. On day after the first IOP:

    a. Those samples that ran on the previous day will be removed. The timer programs will be set to Fixed Off.

6 On the day prior to the next IOP or on the first day of the next IOP:

    a. Sample substrates are loaded on the MOUDIs during the designated times either on the afternoon of the day before the IOP or in the morning of the first day of this IOP.

    b. The timer is programmed to turn the pumps and sampler turning motors on and off at the times and day of the next sample. The timer programs are enabled.

7. Subsequent sample changes will be made following procedures similar to the above.